IMAGINARY FUTURES
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OK COMPUTER by Simon Schaffer

‘Imagine that human beings were used as reading machines. Assume that in order to become reading machines they need a particular training’ (Ludwig Wittgenstein, 1934).

Machines are predictable and humans are not. In celebrated papers of the late 1940s the English mathematician Alan Turing questioned this notion. Having been a wartime cryptographer at Bletchley Park, then a computer theorist at the National Physical Laboratory and Manchester, Turing claimed he had indeed occasionally been surprised by the output of some discrete state machines. But this revealed nothing about the source of surprise, rather it reflected one’s own mentality. The view that machines could never truly surprise was but a version of brainy folks’ snootiness towards mere deduction or computation.[1] Turing gave this prejudice a ready social explanation. A big machine like the new Automatic Computing Engine (ACE) at the National Physical Laboratory would need servants (whom Turing presumed would be women) to run the hardware, but their tasks would soon be absorbed by the machine itself.� When sufficiently routine, even its masters’ tasks could also be taken over by ACE. But ‘they would surround the whole of their work with mystery and make excuses couched in well chosen gibberish’. Intellectuals and bosses liked to think that higher functions could never be automated, because they were informal, discretionary, and startling.[2]

To counter this mystification, Turing distinguished between rules of conduct governing every eventuality, which were not to be had, and laws of behaviour, which might well exist though currently be unknown. Like Ludwig Wittgenstein, with whom he had some unfortunate exchanges about mathematical conventionalism in Cambridge seminar rooms just before the War, Turing reflected on rules and games. Once upon a time, the outcome of horse races was determined by Jockey Club stewards. Now it was thoroughly mechanized by photography. But Turing had a print of a photo finish whose outcome depended on whether six inches of saliva sprayed across the finishing line counted as part of a horse’s head. The rules didn’t say – so the decision had to be referred back to the stewards’ discretion. Criteria for automated judgments could still be vague, even though all might acknowledge the lawlike character of the behaviour involved. He showed the picture to his Manchester colleague, the physical chemist turned social theorist and fierce anti-communist Michael Polanyi. Polanyi gladly used photos of equine spittle in his own 1951 lectures on tacit knowledge and unspecifiable procedures. The distinction between conduct and lawlike behaviour also helped Turing explain how machines could learn. Though the laws of behaviour of a discrete state machine could and would never vary, its conduct might indeed develop in surprising directions. Hence followed a version of the maker’s knowledge argument that one knew with certainty only what one built. The machine/human distinction was just a matter of whether such laws were exhaustively known, not whether one was afterwards surprised by their ways of execution.[3]

The wealth of commentary on Turing’s proposals has attended mainly to the imitation game he then devised. An interrogator communicating solely by teletype with a woman and a discrete state machine is challenged to identify the former. It has now been claimed there are machines which can defeat the interrogator. An American manufacturer of disco dance floors, Hugh Loebner, offers an annual prize to programmers of such machines and to convincingly human humans too.[4] It has also been argued that the Turing Test proved a dead end, a distraction for devotees of artificial intelligence now to be consigned to history. It has been suggested that the imitation game is too easy for the machine, since it displaces someone pretending to be a woman and ignores the full social repertoire through which attributions of intelligence are commonly made. It has been suggested that the imitation game is too stiff, since it tests whether discrete state machines possess specifically human intelligence, not simply any kind of intelligence.[5] I do not propose a further contribution to this debate. I agree with Donald Michie, the Oxford classicist who worked with Turing at wartime Bletchley on cryptography, chess and machine intelligence. Michie has pointed out that there are certainly intelligent but inarticulable human activities which would make the test obselete. Michie thought it understandable but fatal that Turing had defined intelligence in terms of academic communication not craft skills. I also agree with Robin Gandy, another of Turing's closest collaborators and subsequently distinguished mathematical logician, who advises that the celebrated 1950 paper be read not as philosophy but propaganda and that machine programs alone cannot provide the right way to discuss intelligence.[6]

But of all Turing's exegetes, I find the most congenial in Hugh Kenner, eminent literary critic of modernism. Kenner did not assume human action and capacity stable, then wonder whether machines might ever mimic them. Instead, he proposed the investigation of changing human capacity and action, then wondered whether such changes made them more machine-like. 'Imagine that human beings were used as reading machines', Wittgenstein had suggested. What kind of training would be needed to execute this task ? Kenner saw that the imitation game was but one of a long series of projects in technical fakery – Swift's speculations on whether Gulliver was man, machine or horse; Vaucanson's automata; Babbage's analytical engines; Keaton's acting; Warhol's soup tins. The point of this list was to remind us that notions of authentic human capacity and specifically mechanical capability develop in tandem. Kenner remarked that in the prediction that by the century's end discrete state machines would pass a five minute test about 3 times in ten, 'Turing himself was not perhaps allowing for the possibility that people will grow more machine-like'.[7] In fact Turing also seems to have just such a millenial prospect in view: 'the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted'. The imitation game is then less interesting as philosophical propaganda than as historical sociology.[8]

This would be an historical sociology of technology. It has been rightly urged that a history of brain models is really a history of the literary and material technologies which are familiar to, and then used as metaphors by, brain scientists. Their metaphorical menagerie exhibits mental clocks, logical pianos, barrel organisms, neural telegraphs and cerebral computer nets.[9] How do specific technologies get into this zoo ? Claims that certain systems can mimic, or even exhibit, intelligence are sustained by social hierarchies of head and hand. Minds are known because these social conventions are known. Colin Blakemore, an eminent contemporary neuroscientist, describes the brain as 'a biological instrument more complex, more compact, more sophisticated than any machine made by man'. It might therefore seem to escape metaphoric analysis. But no: 'within this enigmatic kilogram-and-a-half of jelly resides a power of computation that embarrasses the weightiest computer_.A computer with so many components and connections could administer the world. Perhaps it is not surprising that a few famous and infamous brains in history have tried to do the same'.[10] Such conventions include those which maintain or question the privileges of discretionary behaviour. Intellectual labour's apparently discretionary character may be subsumed within more determinist regimes if it can be subjected to precise estimation. Then the performance of such labour by machines seems more plausible. There are obvious philosophical counterparts of the components of this argument: materialism, reductionism and determinism are ranged against idealism, emergence and free will. But the story which follows attempts to give these rather olympian philosophical themes a local significance in scientists' interests in taming and analysing underdetermined behaviour by the measurement of intellectual outputs. Since the Enlightenment, neurology, anthropology and physiology have often relied on such measures: oxygen flow, pulse rate, galvanic activity, phrenological charts, cerebral thermometry or – most pervasively – cranial capacity have all been used as markers of underlying brain activity and thus intellectual, social and moral rank. No doubt the instruments used to make such measures then become the source of neurological metaphor.[11] But this kind of cerebral metrology embraces a wider history than that which links craniometry with more recent strategies of intelligence testing and psychometrics. It includes commonplace enterprises which preserve a space for mental life, and define and measure quantitative tokens of that life, so as to show how intellectuals function in economy and society. Cerebral metrology may involve physicochemical monitoring of brains and bodies and competitive examinations to test intellectual achievement; but it also includes assessments of risk which displace cautionary theodicy by social insurance; political economies which show how price formation depends on matters of psychological judgment; or forms of industrial organisation which expropriate embodied skill as allegedly visible productive performance.

The aim of this chapter, therefore, is to suggest how judgements that machines are intelligent have involved techniques for measuring brains' outputs. These techniques show how discretionary behaviour is connected with status of those who rely on intelligence for their social legitimacy. These connections seem rather evident in Turing's own milieu. Protagonists of thinking machines and artificial minds then scarcely doubted the entanglement of brains and culture. In the 1940s, for example, collective organisation and military mobilisation of intellectual labour seemed to make feedback systems acutely plausible representations of human capacity. Cybernetics temporarily convinced those who had lived among (and occasionally as) homoeostatic devices. The political scientist Herbert Simon, future guru of AI, moved via management science and military planning into 'artificial intelligence research into high-order intellectual processes'. Soon he was predicting that within a decade 'most theories in psychology will take the form of computer programs'.[12] In 1950 the English biologist John Zachary Young gave a major series of radio lectures on new models of the brain using the then fashionable language of cybernetics and feedback theory. He mixed the well-established neurological research of Sherrington and Adrian with the up-to-date information theories of Lashley and Wiener. In quick succession he compared the brain with a guided missile system and with a mechanical computer based on networked valves. 'In order to have some picture of how the brain works it is useful to think of it as an enormous ministry whose one aim and object is to preserve intact the country for which it is responsible' – an image utterly familiar to a British audience accustomed to world war and welfare state. Young's version of brain science closely tracked changes in communications technology. He recalled how Cartesian clockwork gave way to Victorian engineering. Had not Thomas Huxley claimed that mind is to brain as whistle is to steam engine ? The brain was obviously the machine which itself generated science; science was just the way good brains worked. Managerialism was the right way to run society and model the brain. 'We do not know much yet about what goes on in our brains and therefore cannot expect educators to educate them properly, psychologists to help us correct their workings, or surgeons to know whether it is wise to cut pieces out of them'. [13]

As he prepared to write up his broadcasts for publication at the end of 1950, Young needed advice on estimating the storage capacity of a brain-like machine. He recalled a meeting at Manchester a year before on 'the mind and the computing machine'. There he debated the computer analogy with Polanyi and Turing. Young, Turing and their contemporaries such as the cyberneticist Ross Ashby (whose homeostatic 'Design for a Brain' first appeared in 1948) were much impressed by state-determined systems completely described by prior position and given imput. Ashby reckoned that such systems were exactly what experimenters achieved in ideal laboratory trials. Young urged that such systems were the best possible models of how neurological systems worked.[14] Polanyi, by contrast, worked hard to show how eliminativist neurology, cybernetics and the vices of Soviet Communism fitted together. He argued that contemporary neurologists reduced their subject matter to measurable variables and so got rid of discretion and will. Cybernetics turned humans into robots. Soviet ideology did the same — and had seduced fellow-travelling intellectuals such as Desmond Bernal because 'rational action becomes a lifeless banality'. Polanyi found his allies among neurologists such as John Eccles and eminent opponents in Turing and Young.[15] Though very sceptical of its metaphysics, Turing knew all about cybernetics. From summer 1949 he joined a London discussion group on the topic with such enthusiasts as Ashby and Warren McCulloch. Soon Turing broadcast for the BBC on whether digital computers could think. Meanwhile, in October 1950 his Manchester paper appeared in the nation's pre-eminent philosophy journal, Mind, under the title 'Computing machinery and intelligence'.[16]

The closing section of Turing's paper was devoted to the problem of building a brain. Anything that could be turned into a routine could be aped by a computer and so plausibly performed by the kind of brain which Young set forth. Young deprecated intellectuals' talk of 'pseudo-things' and 'semi-things' such as consciousness or mind. He claimed that cerebral evolution explained why humans might resist the possibility of treating brains as machines and so replacing one by the other. In February 1947, in a talk to the London Mathematical Society on the operation of ACE, Turing spent some time detailing the social organisation required to tend it and the gibberish with which bosses would try to resist their own automation. 'This topic leads to the question as to how far it is in principle possible for a computing machine to simulate human activities'.[17] Turing insisted that learning machines, the basis of building brains, must possess operating rules which could 'describe completely how the machine will react whatever its history might be, whatever changes it might undergo. The rules are thus quite time-invariant’. For the admirers of state-determined machines the principal puzzle would be the appearance of innovation: ‘intelligent behaviour presumably consists in a departure from the completely disciplined behaviour involved in computation, but a rather slight one, which does not give rise to random behaviour, or to pointless repetitive loops’. Now Turing turned back to the history of his own discipline, citing an 1843 account of Charles Babbage’s project to build a digital computer. In planning his Analytical Engine, Babbage had early developed the notion of conditional branching. As Turing’s biographer sagely remarks, mechanising conditionality ‘would be analogous to specifying not only the routine tasks of the workers but the testing, deciding, and controlling operations of the management‘. Bosses make choices, and intellectuals make reasoned but discretionary ones. The history of such choices might tell us something about the cultural history of thinking machines.[18]

It has been convincingly suggested that the early nineteenth century separation of calculation from intelligence depended on the low status of the mechanics who performed computation and thus made its mechanization then seem viable.[19] Enlightenment ergonomics provided metrologies of work which were then applied to brains and helped make intelligent machines plausible. In the rapid industrialisation of the first decades of the 19th century, theorists of the factory system such as Charles Babbage represented the workforce as a collective machine under intelligent management.� To extend their cultural legitimacy, Babbage and his allies showed that capricious or miraculous change could be the programmed outcome of intelligent mechanism. But when challenged by cultural conservatives, more friendly to priestcraft and the academy, they made sure to preserve a realm of intellect and will. This could help their own command over economic and social resources. By the end of the 19th century, scientific professionals such as Thomas Huxley and his colleagues among the scientific naturalists rapidly gained this command, imposed tests of intelligence and aptitude on the brainpower of the nation, and accounted for the brain as a complex mechanism. They also conceded that the mind might escape such mechanisation – using techniques of precision quantification, they were able to point to those tokens of mental activity which could indeed be subjected to measurement and thus mechanism. The balance of this admittedly Anglocentric paper, therefore, is devoted to the intellectual and social crises of industrialisation in the 1830s and of professionalisation in the 1870s, the cerebral metrologies developed at those moments, and the issues of prediction and underdetermination raised by the evaluation of brain power.

‘The engine knows’

� � ‘The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform. It can follow analysis; but it has no power of anticipating any analytical relations or truths. Its province is to assist us in making available what we are already acquainted with. This it is calculated to effect primarily and chiefly, of course, through its executive faculties’ (Ada Lovelace: Sketch of the Analytical Engine, 1843).

This cautionary text about the unoriginality of digital machines, which Turing cited in 1950, had originally been generated during Babbage’s dramatic publicity campaign for his troubled Analytical Engine. Babbage used contacts such as the Piedmontese military engineer and future premier Luigi Menabrea and then the aristocratic philomath Ada Lovelace. The ‘Sketch of the Analytical Engine’ appeared in journals in Geneva and then London in the winter of 1842-43.[20] It showed the new machine was an unprecedented technical system designed to carry in its memory one thousand numbers each of fifty digits. The store consisted of sets of parallel figure wheels, structured like those in the store of Babbage’s earlier Difference Engine, launched in the early 1820s and still incomplete despite massive government and private investment. Sequences of operation cards carried instructions to the engine, which were decoded in the store using the machine’s library of logarithmic and other functions, and then distributed to the operating sections of the mill. Such distribution could itself be modified by variables set by the existing state of operations in the machine. These crucial aspects of the Engine, its capacity for memory and for anticipation, were to be profound resources for Babbage’s metaphysics and his political economy. ‘Nothing but teaching the Engine to foresee and then to act upon that foresight could ever lead me to the object I desired’.[21] Discussions with his colleagues such as Menabrea questioned Babbage’s account of the knowledge which such complex processes of training and judgement might involve. When Menabrea completed his essay on the machine, he remarked that ‘the machine is not a thinking being, but simply an automaton which acts according to the laws imposed upon it’.[22]

Enlightened savants such as Babbage and his allies well understood the figure of the automaton as a resource for estimating labour power and defining their own managerial role. They were enthusiasts for techniques first developed by the French engineer and academician Charles Coulomb, who after managing colonial military works had tried to evaluate the maximum effect extractible from labour, and the chemist and economist Antoine Lavoisier, who worked out laboratory methods treating all humans as so many machines absorbing vital air and nutriment. They could determine 'how many pounds weight correspond to the efforts of a man who recites a speech, a musician who plays an instrument. Whatever is mechanical can similarly be evaluated in the work of the philosopher who reflects, the man of letters who writes, the musician who composes. These effects, considered as purely moral, have something physical and material which allows them, through this relationship, to be compared with those which a labourer performs'. Lavoisier's chemical technology of self-experiment allowed him to evaluate 'the efforts of the mind as well as those of the body', because all humans were understood as automata labouring in closed exchange systems. By constructing, displaying and imagining such self-governing machine systems, the enlightened supposed they could make their own social order and a powerful place within it. So automata had a salient political function in 'the technologies of rationalism'[23]. Menabrea and his allies worked hard to link this kind of algebraic analysis of human capacities with the urgent practical demands of military and civil engineering and thus to reform the labour force of new states. Babbage's own use of such rationalist resources marked him out as an unusually sympathetic apostle of Enlightenment techniques in early Victorian Britain. In this context, the Analytical Engine was a neat way of accounting for labour discipline alongside intellectual control.

Babbage and Lovelace, who translated and annotated Menabrea's memoir in 1843, used highly anthropomorphic language to describe the faculty of anticipation, feeling and choice which they reckoned the engine would display. Lovelace had her own self-destructive interests in the bodily experiences of doing analysis. Alan Turing strangely echoed some of her own worries when, in a testy passage of his 1950 paper directed against theologians, he pointed out that 'in attempting to construct such [intelligent] machines we should not be irreverently usurping [God's] power of creating souls, any more than we are in the procreation of children'. Lovelace explicitly saw her own frail body as a 'laboratory' for testing currently fashionable materialist theories of mind, especially those of her ambitious young physiological mentor, William Carpenter. Carpenter, Babbage and Lovelace all discussed the effects of mathematical analysis on bodily constitution and of bodily condition on mathematical capacity. Then they applied these lessons to the calculating machines.[24] Babbage conceded that 'in substituting mechanism for the performance of operations hitherto executed by intellectual labour…the analogy between these acts and the operations of mind almost forced upon me the figurative employment of the same terms. They were found at once convenient and expressive, and I prefer to continue their use'. Hence he was committed to phrases such as 'the engine knows', to describe its predetermined move from one calculation to the next.� Lovelace put the issue like this: 'although it is not itself the being that reflects, it may yet be considered as the being which executes the conceptions of intelligence. The cards receive the impress of these conceptions, and transmit to the various trains of mechanism composing the engine the orders necessary for their action'. This execution of intelligence was directly linked to the capacities of reliable subordinate workmen: 'it will by means of some simple notations be easy to consign the execution of them to a workman. Thus the whole intellectual labour will be limited to the preparation of the formulae, which must be adapted for calculation by the engine'. The subordination of machinofacture to intelligence was crucial. The Analytical Engine, like Turing's ACE a century later, raised the issue of the class division of intelligence. Menabrea ended his memoir with a reflection on the 'economy of intelligence'. 'The engine may be considered as a real manufactory of numbers'. In her remarkable annotations to this text, Lovelace extended and qualified these remarks about the manufacture process. She urged that the issue of whether the 'executive faculties of this engine…are really even able to follow analysis in its whole extent' could only be answered by watching the engine work. She explicitly analogized between the working of the machine and the mind, notably in respect of the separation between operation cards, variable cards and number cards. 'It were much to be desired', she noted, 'that when mathematical processes pass through the human brain instead of through the medium of inanimate mechanisms, it were equally a necessity of things that the reasonings connected with operations should hold the same just place as a clear and well-defined branch of the subject of analysis…which they must do in studying the engine'. The science of operations was proposed as a new discipline of utter generality both within the surveillance of cerebral labour and in the manufacture of exact values.[25]

Management of labour's caprices held the key to these connexions. In the decade of political reform and the factory system, Babbage tried to make industry uniquely visible to managers so as to guarantee the reliability of output. One could survey 'not only the mechanical connection of the solid members of the bodies of men' but also, ‘in the form of a connected map or plan, the organization of an extensive factory, or any great public institution, in which a vast number of individuals are employed, and their duties regulated (as they generally are or ought to be) by a consistent and well-digested system’. Under this gaze factories looked like perfect engines and calculating machines looked like perfect computers.[26] These engines for manufacturing numbers were developed alongside the discourse of political economy. The ‘philosophy of manufactures’ provided Babbage with an account of what he called the ‘domestic economy of the factory’. His publications on the economy of the factory and the automatism of labour power culminated in his great survey of 1828-32, On the Economy of Machinery and Manufactures, a work based on intelligence gathered throughout the factories of Britain, soon translated into every major European language. As the calculating engine was a ‘manufactory of figures’, so Babbage sketched his definition of a ‘manufactory’, especially its disaggregation of production processes into their simplest components to allow economy and surveillance in terms of consumed power, wages, or time.[27]

Babbage’s specifications placed unprecedented demands on the skills of the machine tool workshops. A report drafted in 1829 for the gentlemen of the Royal Society by Babbage’s closest allies conceded that ‘in all those parts of the machine where the nicest precision is required the wheelwork only brings them by a first approximation (though a very nice one) to their destined places, and they are then settled into accurate adjustment by peculiar contrivances which admit of no shake or latitude of any kind’.[28] The troublesome terms in these bland remarks by the gentlemen of science were the references to nice precision, accurate adjustment and shake or latitude. What might seem to a savant to be matters of irrational judgement were key aspects of the customary culture of the industrialising workshop. The rights of the workers to the whole value of their labour informed much of the radical protest of these key years. The Chartist workforce protested against the campaigns ‘to make us tools’.� Proletarian visitors to the machine shows equally frequently complained that their own role in manufacture was invisible there. In contrast, Babbage’s colleague ‘the Pindar of Manufacture’ Andrew Ure characteristically lapsed into the imagery of Olympus and of Mary Shelley’s Frankenstein to describe the new automatic machinery as ‘the Iron Man sprung out of the hands of our modern Prometheus at the bidding of Minerva – a creation destined to restore order among the industrious classes’.[29]

These issues made urgent the problem of the source and ownership of the intelligence and skills embodied in machines confessedly designed to perform mental work. In his Economy of Machinery Babbage made much of the means through which the automatic lathe and its product, the calculating engine, would guarantee ‘identity’ and ‘accuracy’.[30] Proponents of machinofacture reckoned that the factory system was evidently a consequence of intelligent reason and situated this intelligence in the complex relation between the fixed capital of the steam-driven engines and the mental capital of the millowners. The workforce itself was only judged a producer of value to the extent that it matched precisely the capacities of the machines. The qualities attributed to this intelligence were just those required from this form of superintendence, anticipation and meticulous scrutiny. This was the definition of intelligence which Babbage embodied in his machines and the sense of intelligence which he reckoned those machines displayed. He even claimed that these were the virtues of divinity. Natural theology was the indispensable medium through which early Victorian savants broadcast their messages. The dominant texts of this genre were the Bridgewater Treatises composed in the early 1830s by eminent divines and natural philosophers under the management of the Royal Society’s presidency.[31] The treatise produced by William Whewell, then mathematics tutor at Trinity College Cambridge, was among the most successful of these. Babbage’s machine philosophy was here assailed from a perspective in complete contrast to those of the radical artisans. Whewell rejected continuities at every level. He invented the word ‘palaetiology’ to describe the rational search for causes of current systems, just so as to point out that this search must always terminate with the inexplicable and spiritual. He denied any material origin for thought or language. He reckoned that discoveries were not made by the patient accumulation of facts but rather by the sudden dramatic superinduction of a fundamental idea which then governed the phenomena. He thought that his students could be drilled to formalise mathematical truths but not taught how to discover them. ‘We cannot unfold the mind of a spider or bee into the� mind of a geometer’. The historical emergence of intelligence from mere matter was itself, for Whewell,� not a lawlike surprise but rather a divine and thus miraculous act. Whewell maintained a consistent hostility to the implications of mechanised analysis: ‘we may thus deny to the mechanical philosophers and mathematicians of recent times any authority with regard to their views of the administration of the Universe’. Worse was to follow. Whewell brutally denied that mechanised analytical calculation was proper to the formation of the clerisy. In classical geometry ‘we tread the ground ourselves at every step feeling ourselves firm’ but in machine analysis ‘we are carried along as in a railroad carriage, entering it at one station and coming out of it at another…..it is plain that the latter is not a mode of exercising our own locomotive powers…It may be the best way for men of business to travel but it cannot fitly be made a part of the gymnastics of education'.[32]

These remarks were direct blows to Babbage's programme.� He called the reply to Whewell he produced in 1837 the Ninth Bridgewater Treatise and labelled it 'a fragment'. It contained a series of sketches of his religious faith, his cosmology and his ambitions for the calculating engines. It amounted to a confession of his faith that the established clerisy was incompetent, dangerous and innumerate. Babbage had shown that memory and foresight were� the two features of intelligence represented in his machines. He now showed, using resources from his calculating engines and from David Hume's notorious critique of miracles and revelation, that these features of machine intelligence were all that was needed to understand and model the rule of God, whether based on the miraculous work of the Supreme Intelligence or on His promise of an afterlife. Foresight could be shown to be responsible for all apparently miaculous and specially providential events in nature. Throughout the 1830s Babbage regaled his guests with a portentous party trick. He could set the machine to print a series of integers from unity to one million. Any observer of the machine's output would assume that this series would continue indefinitely. But the initial setting of the machine could be adjusted so that at a certain point the machine would then advance in steps of ten thousand. An indefinite number of different rules might be set this way. To the observer, each discontinuity would seem to be a surprise, if not a 'miracle', an event unpredictable from the apparent law-like course of the machine. Yet in fact the manager of the system would have given it foresight. Whewell's Bridgewater Treatise appeared at the start of March 1833. Less than two months later Babbage had already worked out a salon experiment using the Difference Engine to print the series of even integers up to ten thousand and then increase each term in steps of three. The sudden discontinuity was predictable to the analyst and yet surprising to the audience. Babbage drew the analogy with divine foresight, whether in the production of new species or in miraculous intervention. In May 1833, therefore, Babbage was ready to show a mechanical miracle.[33]

His onlookers were almost always impressed. As early as June 1833 Lady Byron and her daughter Ada Lovelace 'both went to see the thinking machine (for such it seems)' and were treated to Babbage's miraculous show of apparently sudden breaks in its output. 'There was a sublimity in the views thus opened of the ultimate results of intellectual power', she reported. The dour Thomas Carlyle was predictably sceptical, and thundered his complaint about Babbage's analogy between thought and steam power. 'Innumerable are the illusions of Custom, but of all these, perhaps the cleverest is her knack of persuading us that the Miraculous, by simple repetition, ceases to be Miraculous….Am I to view the Stupendous with stupid indifference, because I have seen it twice, or two hundred, or two million times ? There is no reason in Nature or in Art why I should: unless, indeed, I am a mere Work-Machine, for whom the divine gift of Thought were no other than the terrestrial gift of Steam is to the Steam-Engine, a power whereby Cotton might be spun, and money and money's worth realised'.[34] Two years later a curious visitor was treated to a lecture of three hours on the topic of programmed discontinuities: 'the whole, of course, seems incomprehensible, without the exercise of volition and thought'. Here, then, was the spiritual equivalent of the systematic gaze. In answer to Whewell's boast that only induction might reveal the divine plan of the world, and that machine analysis could never do so, Babbage countered that the world could be represented as an automatic array only visible as a system from the point of view of its manager. The world-system was a macroscopic version of a factory, the philosophy of machinery the true path to faith, and the calculating engines' power of 'volition and thought' demonstrated to all.[35]

Babbage's house-party miracles were not the only way in which London reformers like Charles Darwin learnt about the capacity of machines to mimic sudden and unexpected actions. In the metropolitan anatomy schools where Marshall Hall taught and Thomas Huxley studied in the 1840s, the new doctrine of the reflex arc indicated that the central nervous system functioned like an automatic machine. Hall notoriously sought to distinguish the realm of the cerebrum, the proper governor of the sensory and voluntary nerves, from the more automatic, less capricious, excito-motory nerves. Some went further: the York medical teacher Thomas Laycock argued that since the cranial ganglia were continuous with the spinal cord, they must be regulated 'by laws identical'. Compare this map of structural continuities of law-like determinism with that Babbage drew of the division between the automatism of mechanical labour and the unique privileges of the philosopher and manager. The language and technique of comparative anatomists and neurologists in the mid-century repeatedly questioned, though they tried to preserve, the proper sphere of mind and soul over and above an ever-expanding automatic system.[36] Thus the unitarian medic Carpenter, Lovelace's erstwhile moral confidant and soon the capital's premier physiology professor, wondered whether the cerebrum displayed the reflex functions common elsewhere in the body's system of nerves and ganglia which he so patiently mapped. Somehow there had been an apparently discontinuous ‘increase of intelligence’ and ‘predominance of will over the involuntary impulses’. Eventually Carpenter wrote of cerebral reflexes no less automatic than those of the lower nervous system. Consciousness and will were then strictly limited, and the rule of the neurological machine extended to zones previously the prerogative of mind alone. Thus was forged the careful boundary around what later Victorian philosophers and intellectuals would call ‘the mysterious citadel of the will’.[37]

Carpenter and Babbage argued that a single law could govern the universe’s unfolding, whether in cosmology or physiology. Both attacked Whewell’s donnish claim that divinity, spirit and mind supervened on, and dramatically disrupted, the law-like progression. And both understood the division of labour as apt evidence for the way in which machine-like automatism could generate apparent, but by no means miraculous or inexplicable, innovation.[38] In the 1870s, when the new professionals of the physiological and physical sciences set out to capture the commanding heights of government expertise, industrial science and college jobs, they carried with them this interest in the emergence of novelty from mechanically governed systematic order. Some psychologists and physiologists also reckoned that the security of intellectuals’ new status was dependent on preserving a realm of voluntary action and discretion resistant to reduction. The new tool in their hands was the capacity which men like Babbage had forged – the science of measurement. It had become plausible that natural objects like brains really behaved the way that geared engines did. At the end of his Economy of Machinery� Babbage had described ‘a higher science’ which ‘is now preparing its fetters for the minutest atoms that nature has created: it is the science of calculation which becomes continually more necessary at each step of our progress’.[39] It is significant for this story of the cultural meaning of thinking machines that a prophecy of the universal role of tabulated calculation appears at the end of a text on social organisation of the factory system.

A mechanical equivalent of consciousness

‘I believe that we shall, sooner or later, arrive at a mechanical equivalent of consciousness, just as we have arrived at a mechanical equivalent of heat. If a pound weight falling through a distance of a foot gives rise to a definite amount of heat, which may properly be said to be its equivalent, the same pound weight falling through a foot on a man’s hand gives rise to a definite amount of feeling, which might with equal propriety be said to be its equivalent in consciousness’ (Thomas Henry Huxley, ‘On Descartes’ Discourse’, 1870)

In any recognizable or recognized form, intellectuals first appeared in England around 1870. Gentlemen of letters and of science had not until then been members of a well-defined social class. Their standing had relied on the model of the learned professions – law, medicine and the church. Babbage complained in 1851 that ‘science in England is not a profession: its cultivators are scarcely even recognized as a class’.[40] It has been said that Victorian intellectuals ‘thought of themselves as exchanging specialized products in a market which was tolerably free, and the sum of whose intellectual commodities made up the sum of knowledge’.[41] But neither in political economy nor in materialist metaphysics was it easy to see exactly how to measure the productivity, and thus estimate the value, of this special class. Negative implications quickly clustered in English around the term ‘intellectual’. The airy realm of pure theory, brain rather than brawn, seemed too easily to distance this social formation from the common-sense world of market and home. Aesthetes were satirised as otherworldly; philosophers were viewed as useless on the exchange; experimenters were damned as inhuman vivisectors or as cloistered myopes. So when in the 1830s Whewell’s allies tried to defend their university against the tide of utilitarianism, the philosophic radical John Stuart Mill influentially answered by noting that ‘in intellect’ England was ‘distinguished only for…doing all those things which are best done where man most resembles a machine, with the precision of a machine’. The portentous Catholic theologian Cardinal Wiseman feared that ‘the next generation’ might be ‘brought up in the ideas of many of the present, that man is a machine, the soul is electricity, the affections magnetism, that life is a rail road, the world a share market, and death a terminus’.[42] Either brain power could be precisely estimated, thus bringing brains to market, or else it could be claimed that such valuation was really denigration, so keeping brains sacred.

By the 1870s aggressive positivists and scientific naturalists, cultural critics and ambitious lay experts, all sought recognition as a distinct order. By analogy with the ‘labour aristocracy’ of highly skilled technicians and artisans, there was now an ‘intellectual aristocracy’ which had in the 1850s turned secretive discretionary government into well-oiled administrative machinery and by 1870 had imposed competitive public examinations on the military, the civil service and most cognate institutions.[43] The polite language of intellectual labour changed too. The Oxford English Dictionary (1888), compiled by James Murray and other intellectual aristocrats, carefully recorded the introduction of new terms for cerebral labour and its effects. In 1864 the Poet Laureate, Alfred Tennyson, started using the term ‘brain-labour’. In 1871 novelists invented ‘brainwork’ and psychical researchers started investigating ‘brain-waves’. In 1878 Huxley’s closest friend Joseph Hooker coined the term ‘brain-power’, and the author of a work on The Hygiene of Brain and Nerves began referring to ‘brain-workers’. In the United States, it was reported, one could now be ‘brainy’ (1874) and even suffer from ‘brain-fag’, a term soon picked up by William James. And from 1877 the Brain even had an eponymous learned journal all its own. The physiological psychology of Hall and Carpenter was now an entire professional world. It is thus tempting to link these lexicographic innovations with the ‘new phrenology’ which Brain‘s founders, the metropolitan hospital physicians John Hughlings Jackson and David Ferrier, then developed. These new phrenologists displaced the mapping of mental faculties by the exact energetics of sensory-motor phenomena. There could be no physiology of mind as such: ideas, memories, delirium, verbal slips, were markers for the expanding realm of sensory-motor phenomena. This was when Jackson, for example, introduced the punning term ‘barrel organism’ for the mechanisms of aphasia. ‘Neural physiology is concerned only…with the physics of the nervous system’. This version of cerebral metrology, with its naturalistic and evolutionist implications for the social order and careful explication of its apparent inequalities, provided what has acutely been called ‘a cosmic genealogy for middle-class civilisation’.[44]

So in March 1870 Thomas Huxley came up to Cambridge to tell an audience of young Christians that the true path from Cartesian dualism led to ‘legitimate materialism’ – ‘man is nothing but a machine…capable of adjusting itself within certain limits’. Huxley called this ‘the introduction of Calvinism [understand: predestination] into science’. Exactly three years later Huxley again lectured on animals (and humans) as automata; so the university’s newly hired professor of experimental physics James Clerk Maxwell told a more senior Cambridge audience that such Cartesian metaphysics was just bad physics. Huxley’s fatal mix of Cartesianism and Calvinism was an error based on overconfidence in ‘absolutely perfect data and the omniscience of contingency’. Maxwell explained the cerebral metrology of bad metaphysics: ‘What is the occupation of a metaphysician ? He is nothing but a physicist disarmed of all his weapons – a disembodied spirit trying to measure distances in terms of his own cubit, to form a chronology in which intervals of time are measured by the number of thoughts which they include, and to evolve a standard pound out of his own self-consciousness’. The telling point in this intriguing contrast between the naturalist’s materialism and the physicist’s indeterminism is that both discussed how brain work could be turned into measurement. Huxley judged that a materialist science of consciousness was in prospect because he held that a mechanical equivalent of consciousness could be established. ‘It is because the body is a machine that education is possible’. Maxwell reckoned that no such science was to be had because there was no plausible physical measure of changes in consciousness, whether it be ‘the little word which sets the world a fighting, the little scruple which prevents a man from doing his will, the little gemmule which makes us philosophers or idiots’.[45]

To deny the possibility of a ‘cerebral metrology’ was just to deny the submission of intellectuals to the mundane economy. As Otto Sibum reminds us, the enormous significance of James Joule’s construction of a ‘mechanical equivalent of heat’ for Victorian technical culture and economic life offered the notion of ‘mechanical equivalence’ as an apt way of measuring value[46]. Brain work could be made part of this economy if some token could be found allowing that work to be measured. Huxley, who thought of himself as ‘something of a mechanical engineer in partibus infidelium’,� reckoned there was such a token – hence his appeal to the ‘mechanical equivalent of consciousness’. The pious and scholarly Maxwell held otherwise – hence his argument that the brain was an example of an underdetermined, arbitrary system. In February 1879 Maxwell discussed these matters with Francis Galton, genealogist of the new intellectual aristocracy, author of Hereditary genius, a self-confessedly ‘conscious machine’ then ‘busy with experiments on the workings of my own mind’. Maxwell had already attacked Galton’s hereditarian determinism in his 1873 Cambridge lecture and again in an article on atoms for the Encyclopedia Britannica a couple of years later. Now Maxwell wanted him to consider moments when the course taken by a material system ‘is not determined by the forces of the system’. Such a system ‘invokes some determining principle which is extra physical (but not extra natural) to determine which of the two paths it is to follow…it may at any instant at its own sweet will, without exerting any force or spending any energy, go off along that one of the particular paths which happens to coincide with the actual condition of the system at that instant’. For Maxwell, there were indeed natural systems of such complexity that they lay beyond the grip of the metrology derived from the conservation of energy. In such systems ‘expenditure’ could not be used as a token of real transformation.

Cerebration was exactly such a system. The Maxwellian position reserved a certainly natural realm for brain-work outwith the control of the physical economy.[47]

Institutionalisation of the experimental natural sciences within the universities, and the role of scientific experts in the state, were influentially urged by Huxley and his powerful allies. Political interest focussed on the expansion in public education and mass journalism, on German models of industrial expertise and military might, debates about church authority, about evolution and vivisection. All these themes of the early 1870s helped summon into existence a publicly recognizable intellectual profession.[48] It was just such a group of intellectuals whom Huxley entertained at the Metaphysical Society in London only a few months after his Cambridge lecture with the� painstaking and imaginative anatomy of a frog in the deliberately futile search for the amphibian's soul. It was at such an audience of commercially-minded intellectuals, too, that the 'worldly philosopher' and Manchester professor William Stanley Jevons aimed his remarkable manifesto, The Principles of Science (1874). Jevons urged that brute economic facts were mere reflections of mental phenomena. This was exactly why post-Smithian economics could become an exact science and why physical measurement could be applied to the brain's output: 'The time may come when the tender mechanism of the brain will be traced out, and every thought reduced to the expenditure of a determinate weight of nitrogen and phosphorus. No apparent limit exists to the success of the scientific method in weighing and measuring, and reducing beneath the sway of law, the phenomena both of matter and mind'.[49]

Jevons and his allies among the new marginalist economists showed how the economy could be understood as a mental machine; and they also made sure to reserve an impenetrable zone of pure intellect. So in 1869 Jevons automated logic by turning Boolean algebra and Babbage's calculating engine into a 'logical piano', a device built for him by a local clockmaker designed to automate reasoning.[50] What he judged Babbage's 'exquisite book' on machinery and manufacture also gave Jevons the resources to replace the labour theory of value by a more thoroughly psychophysical account. Consumption would take place if calculations of increases in pleasure overbalanced those of further painful exertion. In 1870 Jevons published in the house journal of the new scientific professionals, Nature, on a series of experiments on muscular exertion which helped convinced him that labour became more painful the longer it was performed. Jevons learnt his experimental techniques directly from Babbage's protocols and indirectly from the ergonomic models of Coulomb and Lavoisier.[51] From� Carpenter's physiological psychology Jevons then deduced two universal laws of the economy which tied economic activity firmly to psychological and measurable principles. Consumption relied on the marginal effect of external impressions on the neurospinal system; production on the differential action of muscles guided by the sensorimotor system towards external objects. The link between automatism and physiological psychology showed how the social order could be incorporated directly into the human frame. Like Carpenter and other admirers of the social cosmology of physiological psychology, Jevons made sure to reserve the realm of mind apart. 'Every mind is thus inscrutable to every other mind and no common denominator of feeling seems possible'; but 'we may estimate the equality or inequality of feelings by decisions of the human mind'. What could be estimated with great precision were the public tokens of these feelings in mechanical exertion, price formation and consumption decisions. These in turn depended on the mechanical behaviour of the reflex system. Marginalist economics treated homo economicus as a thinking machine. As a machine, its economic activity was individualised, quantified and then referred to physiological mechanics. In 1872 the economic journalist Walter Bagehot composed Physics and Politics, a history of economic organisation based entirely on the development of the reflex system as set out by Huxley himself. Huxley then issued Bagehot's text in his influential series of works propagandising for scientific naturalism. Babbage's productive machines here became human machines driven by neurological forces. But because these were machines which could think, a sequestered realm could be left for the exercise of mind, and especially for those of the intellectual analysts who alone could set out the laws which governed all of social and economic life[52].

Competitive public examination of brainpower and expert value, newly introduced in the 1870s, was a triumph for the scientific professionals. Some worried that such quantitative estimates would miss the true qualities of intellect and spirit; others nicely compared examinations with 'engines' to drive social progress.[53] Their introduction might seem subversive of morally strenuous instruction among intellectual elites. Maxwell understood the resistance to testing the tyro intellectuals of a newfangled experimental physics laboratory. 'In the present day', he conceded in October 1871, 'men of science are supposed to be in league with the material spirit of the age, and to form a kind of advanced Radical party among men of learning'. Would lab work for brainy students end up 'tainting their mathematical conceptions with material imagery…

Will they not break down altogether ?' The mechanisms of breakdown and and brain work were the obsession of Victorian Cambridge's intellectual elite. In his study of their manufacture, Andrew Warwick tellingly cites such commentators as Ralph Waldo Emerson on these remarkable 'cast-iron men' and recalls the catastrophic breakdowns during mathematics training of both Maxwell and Galton, the latter of whom had felt as if he had 'tried to make a steam-engine perform more work than it was constructed for'.[54] Cerebral metrology was highly controversial. The head of the new Edinburgh University physics laboratory, Peter Guthrie Tait, judged examination of students' ability in measurement experiments as a good way of testing their intellect. The Cambridge mathematician Isaac Todhunter, Whewell's executor, countered that experimenters should be "born and not manufactured". Both sides charged the other with levelling standards and breeding uniformity. Tait wanted "social entropy" in the laboratory, not the "eternal, hideous, intolerable sameness" of mathematical life. Energetics evidently provided the right language for cerebral metrology.[55]

Maxwell's energetics studied mechanical systems which behaved erratically or capriciously. His first triumph had been an essay on the stability of Saturn's rings. In his campaigns to establish properly exact standards for electrical resistance during the 1860s, he'd had his attention drawn to the puzzles of making mechanical governors which could control the rate of spin of a current-carrying coil. The equations of motion of such homeostatic systems showed surprising irregularities and often escaped complete analysis. In early 1873, a few weeks before his paper attacking Descartes, Huxley and determinism, Maxwell introduced problems about apparently continuous, orderly, mathematical systems which nevertheless displayed sudden discontinuities as questions for Cambridge students.[56] In the 1870s he decided to use this expertise to teach his public the right lessons about the cognitive capacities of machines and the properly secure realm of mind. In dialogue with his Scottish colleagues such as Tait, Maxwell began satirising the capacities of any Laplacean intelligence which claimed complete knowledge of the entire future of a mechanical system. Maxwell reduced this intelligence to 'a finite being', a 'pointsman on a railway line', or, in William Thomson's felicitous phrase, 'a demon'.[57] There was a resonance with the physiological agencies of Jevons' economics, which, unknown to the wilful economic agent, guided decisions about labour and consumption in the busy marketplace of clashing values. The link between indeterminacy, measurement and intellectual life was set forth in 1868 by Norman Lockyer, Nature's founder, and Balfour Stewart, Jevons' opposite number as Manchester physics professor. They wrote of 'a machine of infinite delicacy of construction' such as an electric mine exploded by a long-range telegraphic signal. This was a singular point in the smooth physics of mechanical energy. Then the scientists invited their readers to compare this intriguingly mechanical yet startling system with a living body, and, in particular, with the 'obscure transmutations of energy' in 'the mysterious brain chamber' of a human being acquiring a new truth. In 1871 William Carpenter picked up the theme in a widely read article on 'the physiology of will': he acknowledged the existence of a mechanism of thought, then insisted that 'there is a power beyond and above all such mechanisms — a will which_can utilize the automatic agencies to work out its own purpose'.� Here was a a rude mechanical (rather than a deity) incapable of performing work but able to shift valves without friction or inertia, whose actions surpassed those of contemporary mechanical philosophy and defined a boundary which that science could not transcend.[58] Maxwell and his allies agreed to limit their science's scope in order to scotch the dominion of blind fate and articulate the constitution, and social role of, scientific intellectuals. 'Every existence above a certain rank has its singular points: the higher the rank, the more of them. At these points, influences whose physical magnitude is too small to be taken into account of by a finite being, may produce results of the greatest importance. All great results produced by human endeavour depend on these singular states when they occur', and it was the solemn duty of public scientists to disseminate wider understanding of 'singularities and instabilities' so that the ill effects of materialism and the reduction of humans to mere machines could be corrected and quashed. At the end of his life Maxwell wondered whether the soul was 'like the engine driver, who does not draw the train himself, but, by means of certain valves, directs the course of the steam so as to drive the engine forward or backward or to stop it .'[59]

The demonic implications of Maxwell's account of instability and discontinuity had a long and complex aftermath – in psychical research and theosophy, cybernetics and information science. Michael Polanyi made full use of the demon in his lectures on tacit knowledge in the 1950s. The 'emergence of man and the thoughts of man' must not be understood as passive motions of matter and mind, but rather 'the gradual rise of autonomous centres of decision'. The Maxwellian demon was Polanyi's perfect example of such a centre free from the tyranny of material mechanism. This helped Polanyi contest Turing's apparent attribution of intelligence to digital machines. Autonomous centres, such as human minds, themselves determined what might count as a machine. 'Since the control exercised over the machine by the user's mind is – like all interpretations of a system of strict rules – necessarily unspecifiable, the machine can be said to function intelligently only by aid of unspecifiable personal coefficients supplied by the user's mind'. But in his 1948 talk on intelligent machinery, Turing also emphasised the social basis of this kind of technology. He suggested that 'intellectual activity consists mainly of various kinds of search', among which he singled out 'what I should like to call the 'cultural search'. The isolated man does not develop any intellectual power. It is necessary for him to be immersed in an environment of other men. From this point of view the search for new techniques must be regarded as carried out by the human community as a whole, rather than individuals'.[60]

This paper has offered some historical remarks about the new techniques of mechanical intelligence and the communal cultures sustaining them. Babbage's automated conditionality was a decisive moment in the history of these techniques, because he used startling outputs to show how even the most dramatically surprising events in his culture could be quantified and programmed. When intellectuals appeared in England as a specific class formation, debates about the scope of cerebral metrology, automation and determinism became correspondingly intense. In such images as Huxley's mechanical equivalent of consciousness, and Maxwell's cunning proletarian pointsman, Victorians worked out ways of redefining the role of the intellectual in the social economy. By finding proxies for mental life in variables which could be measured the system of thinking machines gained plausibility within a carefully defined but nevertheless rather extensive realm. Processes which are deemed machine-like can therefore be mechanised. It is true that 'the cliché example' of such a process has been the Taylorist ideal of production-line work. Resistance to thinking machines is sometimes bound up with resistance to (or satires of) Taylorisation. It is for this reason that Kenner neatly connects the imitation game with the on-screen antics of Keaton and Chaplin. One correspondingly cliché example of unmechanisable work is the artisan ideal of craft workshop culture. In cultures where administrative discretion and capricious coteries are seen as the principal threat to social virtue, mechanisation and predictability seem like ideals. In those where automation and expropriation of skill are seen as insidious, the tacit and irremediably embodied will be praised.[61] This is why judgments that some machines can think or that brains are well represented by such machines are of necessity implicated in rival accounts of the socioeconomic order. The hardware of cerebral metrology does more than provide the material for the neurological imagination. It also helps provide the brain with its cultural and economic place.

'OK Computer' is published in Michael Hagner (ed.), Ecce Cortex: Beitraege zur Geschichte des modernen Gehirns, Wallstein Verlag, 1999, pp. 254-85.

Footnotes

I thank Robin Boast, Gerd Gigerenzer, Michael Hagner, Emily James, Anna-Katherina Mayer, Andrew Mendelsohn, Helmut Mueller-Sievers and Alison Winter for help with the themes of this paper.

[1] Alan Turing: Computing Machinery and Intelligence. Mind 59, 1950, S.433-60, S. 450-1.

[2] Andrew Hodges: Alan Turing: the Enigma. London. 1992, S. 357.

[3] Turing 1950, S. 452, 458; Michael Polanyi: Personal Knowledge: towards a post-critical philosophy. London. 1958, S. 20.

[4] Charles Platt: What's it mean to be human anyway ?. Wired 1, April 1995, S. 80-85.

[5] Blay Whitby: The Turing test: AI's biggest blind alley ?. In P.J.R.Millican and A.Clark (Hg.), Machines and Thought: the Legacy of Alan Turing. Oxford. 1996, S. 53-62; Hubert Dreyfus: What Computers Still Can't Do Cambridge, MA. 1992, S. 78; Robert French: Subcognition and the limits of the Turing test. Mind 99, 1990, S. 53-65; H.M.Collins, Artificial Experts. Cambridge, MA. 1990, S. 186-97.

[6] Donald Michie: Turing's Test and Conscious Thought. Artificial Intelligence 60, 1993, S. 1-22; Robin Gandy: Human versus Mechanical Intelligence. in Millican and Clark 1996, S. 125-36.

[7] Ludwig Wittgenstein: Blue and Brown Books. Oxford 1975, S. 120; Hugh Kenner: The Counterfeiters. Bloomington. 1968, S. 123. Siehe Dreyfus 1992, S. 280.

[8] Collins 1990, S. 222-24.

[9] Jamie Kassler: Man a musical instrument: models of the brain and mental functioning before the computer. History of science 22, 1984, S.59-92; Gerd Gigerenzer: Discovery in cognitive psychology; new tools inspire new theories. Science in context 5, 1992, S. 329-50; and especially Gerd Gigerenzer and Daniel Goldstein: Mind as computer: the birth of a metaphor, 1994.

[10]� Barry Barnes and Steven Shapin: Head and hand: rhetorical resources in British pedagogical writing 1770-1850. Oxford Review of Education 2, 1976, S. 231-54; Colin Blakemore: The baffled brain. In: Richard Gregory and Ernst Gombrich (Hg.): Illusion in nature and art. London 1973, S. 9-48, S.9-11.

[11] Steven Shapin: The politics of observation. Cereberal anatomy and social interests in the Edinburgh phrenology disputes. Sociological Review Monographs 27, 1979, S. 139-78; Stephen Jay Gould: The Mismeasure of Man. New York 1981; Anson Rabinbach: The Human Motor. Berkeley 1990; Anne Harrington: Medicine, mind and the double brain. Princeton 1989, S.113.

[12] Hugh Kenner: The Mechanic Muse. New York 1987, S. 109; Hans Ulrich Gumbrecht and Ludwig Pfeiffer, (Hg.),� Materialities of Communication. Stanford 1994, S. 292, 329-32; Peter Galison: The ontology of the enemy: Norbert Wiener and the cybernetic vision. Critical Inquiry 21, 1994, S. 228-66; Vernon Pratt: Thinking Machines: the evolution of artificial intelligence. Oxford 1987, S. 212-14; Dreyfus 1992, S. 82.

[13] J.Z.Young: Doubt and certainty in science: a biologist’s reflections on the brain. New York. 1960, S. 49, 55.

[14] W.Ross Ashby: Design for a Brain: the origin of adaptive behaviour.� London. 1960, S. 25-6, 270.

[15]� Polanyi 1958, S.158-9, 237, 262-3.

[16] Hodges 1992, S. 415, 436; Young 1960, S. 137; Turing 1950.

[17] Young 1960, S. 50-1, 156; Hodges 1992, S. 357.

[18]Turing 1950, 459, 451; Hodges 1992, S. 298; Bernard Dotzler u. Friedrich Kittler (Hg.): Alan Turing: Intelligence Service. Berlin. 1987, S.227. Siehe Harry Braverman: Labour and Monopoly Capital. New York. 1974, S. 213-33; Alfred Sohn-Rethel: Intellectual and Manual labour. London. 1978, S. 170-4.

[19] Lorraine Daston: Enlightenment calculations. Critical Inquiry 21, 1994, S.182-202, S.186.

[20] Ada Lovelace: Sketch of the Analytical Engine by L.F.Menabrea. Taylor’s Scientific Memoirs 3, 1843, S. 666-731, S.722. Siehe Charles Babbage: Passages from the Life of a Philosopher. London. 1864, S. 112-41; Anthony Hyman: Charles Babbage: Pioneer of the Computer. Oxford. 1982, S. 164-73; for Ada Lovelace’s role see Dorothy Stein: Ada: a Life and a Legacy. Cambridge, MA. 1985, S.� 108-20 (who plays down her originality) and Betty Alexandra Toole: Ada, the Enchantress of Numbers. Mill Valley, CA. 1992, S. 194-260 (who emphasises it).

[21] Babbage 1864, S.114.

[22] Babbage 1864, S. 129-35; Lovelace 1843, S. 675.

[23] Charles Coulomb: Théorie des machines simples. Paris. 1821, S. 260. Siehe C. Stewart Gillmor: Coulomb and the Evolution of Physics and Engineering in Eighteenth-century France. Princeton. 1971, S. 23-4 u. François Vatin: Le Travail: Economie et Physique 1780-1830. Paris. 1993, S. 42-3. Antoine Lavoisier and Armand Seguin: Première mémoire sur la respiration des animaux. 1790. In Oeuvres. 6 Bdd. J.B.Dumas and E. Grimaux (Hg.). Paris. 1864-96. Bd. 2, S. 688-703, S.697. Siehe Bernadette Bensaude Vincent: Lavoisier: Mémoires d’une Révolution. Paris. 1993, S. 220; M. Norton Wise: Mediations: Enlightenment

Balancing Acts or the Technologies of Rationalism. In Paul Horwich (Hg.), World Changes: Thomas Kuhn and the Nature of Science. Cambridge, MA. 1993, S. 207-56, S. 220.

[24] Turing 1950, S. 443; Alison Winter: A calculus of suffering: Ada Lovelace and the bodily constraints on women's knowledge in early Victorian England. In Steven Shapin and Christopher Lawrence (Hg.), Science incarnate. Chicago. 1998, S. 202-39.

[25] H.W.Buxton: Memoir of the Life and Labours of the late Charles Babbage. R.A.Hyman� (Hg.) Cambridge, MA.. 1988, S. 216 Anm.8; Lovelace/Menabrea� 1843, S. 675, 689, 692, 723. For the ambitions for a new science see Toole 1992, S. 209-16.

[26] Babbage: On a Method of Expressing by Signs the Action of Machinery. Philosophical Transactions 116, 1826, S. 250-65 and draft in Cambridge University Library MSS ADD 8705.21 ; Dionysius Lardner: Babbage's Calculating Engines. Edinburgh Review 59, 1834, S. 263-327, S. 318-319. Iwan Morus: Manufacturing Nature: Science, Technology and Victorian Consumer Culture. British Journal for the History of Science 29, 1996, S. 403-34 discusses the relation between commodification and the show of machines in the early Victorian period.

[27] Maxine Berg: The Machinery Question and the Making of Political Economy 1815-1848. Cambridge 1980, S. 182-89; Babbage: On the Economy of Machinery and Manufactures. London 1835, S. 120, 175. Siehe Richard M. Romano: The Economic Ideas of Charles Babbage. History of Political Economy 14, 1982, S. 385-405, p. 391.

[28] Buxton 1988, S. 86.

[29] E.P.Thompson: The Making of the English Working Class. Harmondsworth 1968, S. 889, 915; John Rule: The Labouring Classes in Early Industrial England. London 1986, S. 357-63; Andrew Ure: The Philosophy of Manufactures. London 1835, S. 367.

[30] Babbage 1835, S. 67.

[31] W.F.Cannon: The problem of miracles in the 1830s. Victorian studies 4, 1960, S. 5-32.

[32] William Whewell: Astronomy and General Physics Considered with reference to Natural Theology. London� 1834, S. 334; Ders.: Indications of the Creator. London 1846, S. 44; Ders.: Of a Liberal Education in General. London� 1845, S. 40-41. Siehe Richard Yeo: William Whewell, Natural Theology and the Philosophy of Science in mid-nineteenth-century Britain. Annals of Science 36, 1979, S. 493-516, u. George Stocking: Victorian anthropology. New York 1987, S. 69-70.

[33] Babbage: Ninth Bridgewater Treatise.� London 1838, S. 32-43; Babbage's first experiment with the Difference Engine, 18 May 1833, Cambridge University Library MSS ADD 8705.38 p.38. Siehe William J. Ashworth: Memory, efficiency and symbolic analysis: Charles Babbage, John Herschel and the industrial mind. Isis 87, 1996, S. 629-653.

[34]Lady Byron an King, 21.6. 1833. In Doris Langley Moore: Ada Countess of Lovelace. London 1977, S.44; S.E. de Morgan: Memoir of Augustus de Morgan. London 1882, S. 89; Thomas Carlyle: Sartor Resartus. London 1931, S. 232.

[35] George Ticknor: Life, Letters and Journals. London 1876.

[36] Brian Dolan: Representing novelty: Babbage, Lyell and experiments in early Victorian geology. History of Science 36, 1998, S. 299-327; Stephen Jacyna: Scientific Naturalism in Victorian Britain. PhD thesis. University of Edinburgh 1980, S. 161-73; Harrington 1987, S. 32-33; Adrian Desmond: Huxley. Harmondsworth 1998, S. 15-1

> Within this MySpace version of the electronic agora, cybernetic communism was mainstream and unexceptional. What had once been a revolutionary dream was now an enjoyable part of everyday life.

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